Contract No. NASw - 572

Westinghouse Reference WGD - 38521

RESEARCH ON FAILURE FREE SYSTEMS

Quarterly Report No. 3

Covering the period April 20, 1964 to July 20, 1964

Prepared for:

The National Aeronautics and Space Administration
Washington, D. C.

Westinghouse Defense and Space Center

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A. INTRODUCTION

This quarterly report is prepared in accordance with the requirements of contract NASw-572, "Research on Failure-Free Systems", between the Westinghouse Electric Corporation and the National Aeronautics and Space Administration. The report describes the work which has been done on the four major tasks described by Amendment No. 1 of this contract. The period covered by this report corresponds to the first quarter of the contract extension established by the same Amendment. The work to date represents completion of approximately 17% of the anticipated effort.

[redacted]

B. PROGRAM OBJECTIVE

The general objective of this research program is to develop new techniques that will advance the state-of-the-art concerned with ultrareliable electronic systems. Techniques are being considered which are expected to result in significant increases in the reliability of vital electronic systems. These increases will be realized by giving the systems the capability to withstand a large percentage of internal component failures without degradation of system functional operation. The scope of this program includes the study of error detecting and error correcting codes, the problems associated with using redundant equipment, new schemes for permitting redundant system reorganization in response to changing failure patterns, adaptive logic networks and others.

C. ACTIVITY BY TASKS

The four major tasks of the current contract extension are:

I. Statistical measure of quality
II. Adaptive voter
III. Failure responsive system organizations (self-repair)
IV. Medium communication

A brief summary of the work proposed for each of these tasks is presented below with a review of the progress made to date on each task.

Task I. Statistical Measure of Quality

The object of this task is to develop a method for accurately evaluating the reliability of redundant systems which may contain internal component failures at the time the evaluation is made. Particular attention is to be given to making high confidence reliability estimates based on the analysis of partial system test results. Estimates based on partial system tests are often essential for the effective use of redundant systems because of the high cost of system failures and the high cost of delays required for complete tests.

The effort on this task began June 29, 1964. Although this represents approximately a two-month delay in starting the effort, no difficulty is anticipated in completing the task within the contract year.

Since the beginning of the effort, a detailed study has been made of the possible sources of error which might be made in estimating system reliability under various test conditions. Several possible criteria to which an optimum estimation method might be referenced have been considered. Work is now proceding on the selection of one of these criteria as best reference point for the remainder of the study.

Task II. Adaptive Voter

This task is concerned with the development of a new implementation of the restoring (or voting) circuits required by multiple-line redundant systems. It has been shown analytically that voting circuits with certain adaptive capabilities are potentially more effective in combating the effects of failures than are the currently used majority-voting circuits. The specific object of this task is to design, construct, and test an adaptive voting circuit which will include the most recent advances in adaptive circuit components which are known to the state-of-the-art.

As originally scheduled, the work on this task is not expected to begin until the third quarter of the new contract period established by Amendment 1.

Task III. Failure Responsive System Organizations

This task is intended to be a continuation of the "Self-Repairing Systems" study which began during the first year of this contract. It was shown in that study that systems which have the capability to partially reorganize their redundant subsystems in response to existing internal failure patterns may be more resistant to early life system failures than comparable fixed redundant systems. The first goal of this study is to develop design rules and implementation techniques which will make such systems practicable. The second goal is to design a specific study vehicle which can be used to demonstrate the feasibility of such systems.

The majority of the effort performed on this task during this quarter has been oriented toward the development of the design rules. The computer simulation program written for the earlier phases of this program was not considered to have adequate flexibility for this study. As a result, a new program has been written using many of the minor concepts of the original program, but based primarily on a "spare list" technique. This technique permits a much broader range of system parameters to be tested. The new program has been checked out and is now being used in the study. Although a detailed description of the program will be deferred until a later formal report, a brief summary is given below.

A system organization to be simulated is introduced to the computer in a form very similar to that of the earlier simulation program. The system is represented by a three-dimensional matrix with one dimension corresponding to the stages in the system, a second dimension corresponding to the order of redundancy found within the system and a third dimension corresponding to the data words to be remembered about each individual signal processor. In the new program the data words associated with each processor include a complete "spare list." This list specifies the set of processors which can be sequentially called from the rest of the system to replace each failed processor that becomes a part of a strategic pattern. The data is read into the computer as a simple list of

processor identification numbers. Using this listing method, almost any conceivable sequence of spares can be established by simply modifying the "spare list" input data. This is in marked contrast to the reprogramming previously required to generate new sequences.

In addition to the input "spare list" a number of other control variables are read into the computer to simulate specific system organizations. These variables affect system characteristics such as the capability of certain processors to perform multiple repairs, the minimum amount of instantaneous failure masking required, and the relatively reliability of the processors and the perpherial switching circuitry.

Using this computer program, a wide variety of different experiments can be run by simply varying the input data to the program. Experiments are now being performed to test such items as:

1. Feasibility of systems using less than order three redundancy
2. Optimal system organizations to achieve 100% instantaneous failure masking for more than one failure per stage
3. Optimal system organizations to achieve longest useful system life.

The combined results of these and other experiments are expected to supply the information which is necessary for the formulation of useful rules to govern the design of failure responsive systems.

A new criterion for evaluation has also been developed for this study which permits a single value measure of effectiveness to be associated with each system organization under test. Provisions have been made for incorporating the calculations required to determine the value of this measure into the computer program. This facilitates a quick and relatively accurate evaluation of system performance.

Task IV. Medium Communication for Module Reorganization

The primary goal of this task is to explore the advantages and limitations of systems which have the capability to relate their component subsystems through signals transmitted in a medium rather than over wired and switched signal paths. As part of the investigation, modules will be postulated which can select appropriate input signals from those found in the medium, and, in turn, supply output signals to the same medium. The object in performing this investigation is to determine if a technique such as this can be used to implement failure responsive systems in a more reliable manner than can be achieved using more standard techniques.

The effort on this task has not yet been started because of a personnel scheduling problem. Because this investigation is expected to run for only a few months, however, the delay has not resulted in any changes other than a slight shift in the scheduled investigation period. It is expected that the investigation will begin during the second quarter.

D. MANAGEMENT AND PERSONNEL

The management of this contract continues to be performed by the Advanced Development Subdivision of the Surface Division of the Westinghouse Electric Corporation. The management personnel directly involved in the program include:

Mr. Sidney E. Lomax, Director of Development.

Mr. Allen B. Walls, Supervisor

The technical personnel assigned to the program during this contract quarter include:

Mr. William C. Mann, Project Engineer

Mr. Harvey I. Eisenberg

Mr. Joseph M. Hannigan

Mr. Charles G. Masters, Jr.